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Forecasting Inflation in Sudan

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Forecasting Inflation in Sudan

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Abstract

This paper forecasts inflation in Sudan following two methodologies: the Autoregressive Moving Average (ARMA) model and by looking at the leading indicators of inflation. The estimated ARMA model remarkably tracks the actual inflation during the sample period. The Granger causality test suggests that private sector credit and world wheat prices are the leading indicators explaining inflation in Sudan. Inflation forecasts based on both approaches suggest that inflationary pressures for 2009 and 2010 will be modest and that inflation will remain in single-digits, assuming that prudent macroeconomic policies are maintained.

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I. INTRODUCTION

Forecasting inflation is key for a central bank to adjust its monetary policy to control inflation. Regardless of its monetary policy framework—broad money growth target, nominal exchange rate target, or inflation target—stabilizing inflation is a primary objective of monetary policy. Since inflation levels are, to some extent, a result of past monetary policy and exogenous shocks, the current inflation levels may not give sufficient information for forecasting inflation in the future. Therefore, the central bank needs some "plus alpha" to link current developments to its inflation forecasts.

The necessity of accurate and reliable inflation forecasts is perhaps even more relevant for the Central Bank of Sudan (CBoS) than for central banks of other low income countries. The CBoS faced difficult policy challenges in 2008. On the one hand, there was a liquidity shortage caused by the accumulation of domestic arrears by the government and a need to inject liquidity in the system.[2] On the other hand, the challenge was to control the spike in inflation—higher than 20 percent during its peak in the third quarter of 2008—due to a surge of world food prices. In these circumstances, an injection of high-powered money may have amplified inflationary pressures to the economy. Therefore, accurate inflation forecasts are critical for the CBoS to formulate and implement its monetary policy, particularly under the circumstances it was facing in 2007 and 2008.

The scope of this paper is limited to forecasting inflation, not analyzing the determinants of inflation in Sudan and their policy implications, which have been discussed elsewhere (see Moriyama (2008)). The main challenge in forecasting inflation in low income countries is lack of data availability together with potential instability in structural parameters. While data on inflation, monetary aggregates, nominal exchange rate, and some proxies for supply shocks, such as world commodity prices, are available on a monthly basis, high frequency data on productivity and aggregate demand are not available in Sudan. This makes it difficult to forecast inflation by applying the conventional models used in the existing literature. In order to balance a trade-off between (i) a sample size that should be large enough to apply (asymptotic) econometrics and (ii) the need to address statistical problems associated with structural changes, the paper only uses recent monthly data, in particular from January 2000.

There are several approaches to forecasting inflation. While using the vector autoregressive (VAR) model is popular,[3] this paper focuses on (i) the autoregressive moving average (ARMA) model and (ii) looking at leading indicators—variables that are considered to either cause or predict inflation. Both approaches are simpler and require less data than VAR models. The

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[2] Sudan accumulated domestic arrears in the second half of 2006 and 2007 due to fiscal difficulties, causing severe liquidity shortage in the financial system. The subsequent clearance of domestic arrears, which requires larger transfers to subnational governments, also make implementation of monetary policy more complicated.

[3] Moriyama (2008) estimated inflation dynamics in Sudan applying the VAR model.

results show that the ARMA model has remarkable explanatory power: more than 90 percent of inflation fluctuations can be explained by the estimated model during the sample period (January 2000 to October 2008). Furthermore, the Granger causality test—a test to examine variables predicting inflation—suggests that private sector credit growth and international wheat prices are the leading indicators of inflation. The nominal exchange rate and broad money supply are not considered leading indicators because of their weak two-way causality, probably reflecting that the two variables are policy variables for the central bank.

Although the estimated ARMA model demonstrates good fitness to the actual inflation during the sample period, there is no guarantee that the model can forecast inflation for the future as well. In order to investigate this further, the paper computes the forecasted inflation and its confidence interval for July 2007 to December 2008—a period associated with a surge of inflation. The results suggest that the model still tracks the actual inflation well once external shocks are taken into account.

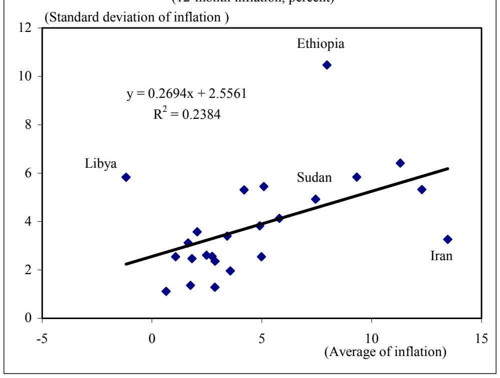
A more interesting exercise for the central bank is to forecast future inflation based on the estimated model and the projections of the leading indicators. Inflation forecasts for 2009 and 2010 by the ARMA model based on information available as of October 2008 suggest that inflation will decline to single digits before the end of 2008 and will stay in single digits during 2009 and 2010. Also, inflation forecasts based on the two leading indicators—private sector credit growth and world wheat price inflation—indicate that inflationary pressures will be small or even negative during 2009 and 2010, in line with the forecast based on the ARMA model. It should be emphasized, however, that a change in policy, for example, an expansionary fiscal stance that could, *inter alia*, put pressure on the exchange rate, could result in a jump in inflation.

The remainder of the paper is organized as follows. The next section briefly presents recent developments of inflation in Sudan. Section III highlights the methodology used in the paper. Section IV presents the results of the estimated ARMA model and the Granger causality test to determine what are the leading indicators of inflation in Sudan. Inflation forecasts for 2009 and 2010 are investigated in Section V. The final section presents conclusions.

II. Recent Developments

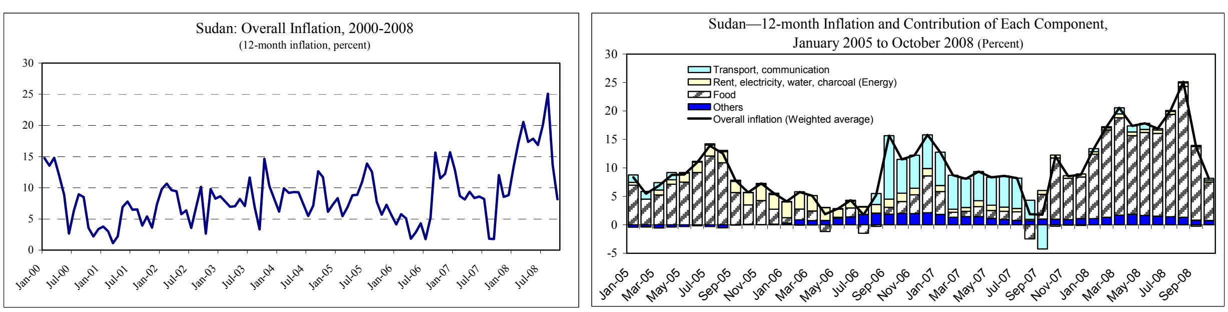
Sudan's annual inflation has averaged 7.5 percent since January 2000, about the same as for the Middle East and North African (MENA) region during the same period (Figure 1).[4] Inflation volatility in Sudan—measured by its standard deviation—is slightly higher. However, this is not substantially larger the standard deviation implied by cross country data, derived from the relation between the average inflation and the standard deviation implied by these countries. The standard deviation of inflation is much larger in Libya, and smaller in Iran than that of other countries given their average inflation.

Figure 1: Average and Standard Deviation of Inflation, 2000-08, MENA and Selected African Countries
(12-month inflation, percent)



Sudan's inflation since 2000 has generally remained in the single digits (Figure 2).[5] There have been, however, two periods when inflation increased above single digits for more than three months (left portion in Figure 2). One episode, from September 2006 to February 2007, was mainly due to a surge in transportation prices as a result of a cut in fuel subsidy in August 2006 while the other episode, from January to September 2008, was due to a spike of bread prices, reflecting a surge of world wheat prices (right portion in Figure 2). Including these two periods, inflation appears to be a stationary process without any structural changes, suggesting that time series econometrics models can be applied to forecast inflation.

Figure 2. Monthly Inflation (12-month) in Sudan, January 2000-October 2008



[4] In addition to 19 countries from Middle East and North African region, Cameroon, Ethiopia, Kenya, Nigeria, and Tanzania are also included.

[5] Sudan has recently moved to new CPI base (2007=100). Inflation data for Sudan in this note are based on the old CPI (base 1990=100) released by the Central Bureau of Statistics, unless otherwise mentioned.

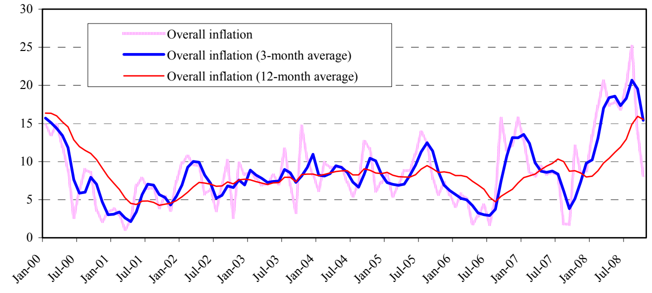
III. METHODOLOGY

A. Which Inflation Should Be Forecasted?

The choice of inflation to be forecasted is the first step in formulating monetary policy. There are a couple of considerations: (i) the inflation should not be contaminated by very short-term shocks which the central bank should ignore for its monetary policy; but (ii) the inflation should track the developments of the underlying inflation as timely as possible.

Averaging inflation over several months is a common practice to filter very short-term fluctuations from the original time series. Figure 3 plots three different measures of overall inflation: overall CPI inflation; 3-month average CPI inflation; and 12-month average CPI inflation. The figure clearly demonstrates that averaging inflation reduces short-term fluctuations as the 3-month average inflation and the 12-month average inflation are much smoother than the original inflation. However, average inflation tends to be lagged to the original inflation. For the latter observation, the 12-month average inflation shows significant delay to the original inflation, suggesting that the 12-month inflation does not track in a timely manner developments in actual inflation, while the delay of the 3-month average inflation to actual inflation is much smaller than that of the 12-month average inflation.

Figure 3. Sudan: Overall Inflation, 2000-2008
(12-month inflation, percent)

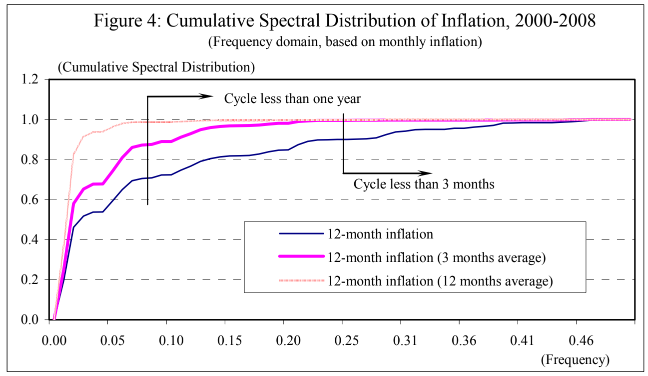


Spectral analysis[6] provides useful statistics to summarize how much a time series contains short-term fluctuations. The purpose of the analysis is to decompose a complex time series with cyclical components into a few underlying sinusoidal (sine and cosine) functions of particular wavelengths. The wavelength of a function is typically expressed in terms of the number of cycles per unit of time (frequency), while the period is defined as the length of time required for one full cycle, i.e., the period is given as the inverse of the frequency.[7]

[6] Compared to the usual time series analysis, called "time domain," the spectral analysis is called "frequency domain" analysis. For a technical discussion on the spectral analysis, see Hamilton (1994) and Wei (1990).

[7] For example, the length of one period is three months when its frequency is 0.33 (1/0.33=3).

Figure 4 presents the estimated cumulative spectrum distribution of the original inflation, the 3-month average inflation, and the 12-month average inflation, where the inverse of the number on the horizontal axis (frequency) give the length of one full cycle of fluctuations. The figure suggests that (i) the original inflation is very noisy because about 10 percent of its fluctuations have cycles less than three months and about 30 percent of its fluctuations have cycles shorter than one year; (ii) the 3-month average eliminates almost all very short-term fluctuations because the share of fluctuations with cycles shorter than 6 months—equivalent to frequencies larger than 0.16 in the figure—decline to nearly zero, significant improvement compared to the original inflation; and (iii) the 12-month average extracts only fluctuations with cycles longer than one year (equivalent to frequencies smaller than 0.08 in the figure).



The paper focuses on the 3-month average inflation to forecast inflation in Sudan, as it would eliminate very short-term fluctuations, as well as track actual inflation better than the 12-month average inflation. Using average inflation would help improve the fitness of the econometric models used for forecasting inflation in the paper.

B. Autoregressive Moving Average (ARMA) Model

This paper uses the Autoregressive Moving Average (ARMA) model to forecast the 3-month average inflation in Sudan because of its simple structure and its minimum data requirements. ARMA (*p*, *q*) model forecasts inflation at period t as the linear projection of (i) inflation from period $t-1$ to $t-p$, autoregressive (AR) part, and (ii) white noise from period t to $t-q$, moving average (MA) part, given an assumption that inflation is stationary process (equation (1)).

$$\pi_t = \beta_0 + \sum_{i=1}^{p} \beta_i \pi_{t-i} + \varepsilon_t + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} \tag{1}$$

The parameters in equation (1) are estimated using the Maximum Likelihood Estimates (MLE) method, assuming that error term (ε) is white noise and follows the normal distribution.

This simple structure of ARMA (*p*, *q*)—which needs only current and past inflation—has several advantages. However, it is difficult to determine the specification of the model, since ARMA models are atheoretic. While economic theory suggests that money supply affects inflation, nominal appreciation reduces inflationary pressures, and a widening output gap causes inflation, ARMA models cannot explicitly incorporate these insights.

The absence of economic theory in ARMA models, therefore, requires other criteria to determine the specification of the model, in particular, the choice of the number of autoregressive terms (p) and moving average terms (q) in equation (1). This paper chooses the best ARMA model to forecast inflation by applying the following three steps. The first is to test serial correlation of residuals using the Breusch-Godfrey Lagrange Multiplier test.[8] The second step is to test whether residuals follow the normal distribution using the Jarque-Bera test.[9] The two steps verify whether the specification of the ARMA model is consistent with the assumption of the MLE: the error term is white noise and follows the normal distribution. Otherwise, the ARMA model cannot be estimated appropriately by the MLE method. The third step is to pick the model with the smallest value of the Schwartz Information Criterion (SIC)[10] among the models which are qualified by the first two steps.

While equation (1) does not include explanatory variables other than lags of inflation and residuals on the right hand side, some exogenous factors may affect inflation dynamics. The paper considers two sets of dummy variables. The first is a set of dummy variables which capture the reduction of fuel subsidies in August 2006. The reduction contributed to a surge in inflation in 2006 and 2007. The other is a set of seasonal variables that coincide with the Islamic calendar to capture a sudden shift in consumption behavior during certain Islamic holidays.[11]

Liquidity assets indicators, which are considered to be correlated with consumption, demonstrates clear comovements with the Islamic calendar variables (Figure 5), suggesting that the use of Islamic calendar variables could improve the explanatory power of the estimated model. Different from the past studies on the Islamic calendar variables, however, these may not be significant in this paper, due to using the 3-month averaged inflation instead of the original inflation in the model in order to eliminate very short-term fluctuations.

[8] See Wooldridge (2000).

[9] Bera and Jarque (1980, 1981).

[10] The Schwartz Information Criterion is statistics used for selecting the lag length in autoregressions. For detailed discussion, see Appendix I.

[11] Sudan, like many other Islamic countries, strictly follows the lunar based Islamic Hijra calendar. Consumption and hence the demand for currency increases during certain months and festivities relative to other months. Variables for the months of Ramadan, Shawal, and Zil-Haja are used to capture this impact. In most Islamic countries, the demand for currency increases temporarily during these periods and reverts back after the festivities are over. In particular, consumption increases during the month of Ramadan, Eid-ul-Fitr, and Eid-ul-Adha.

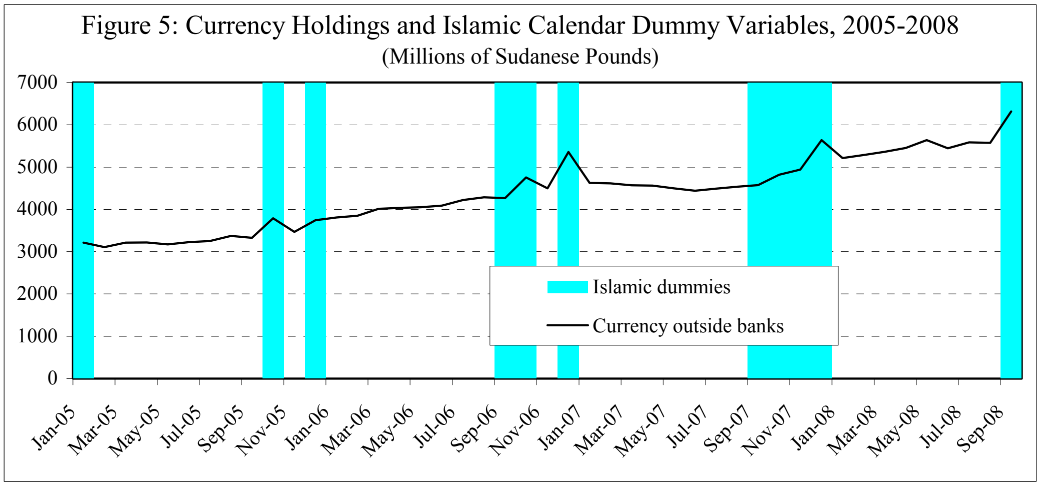


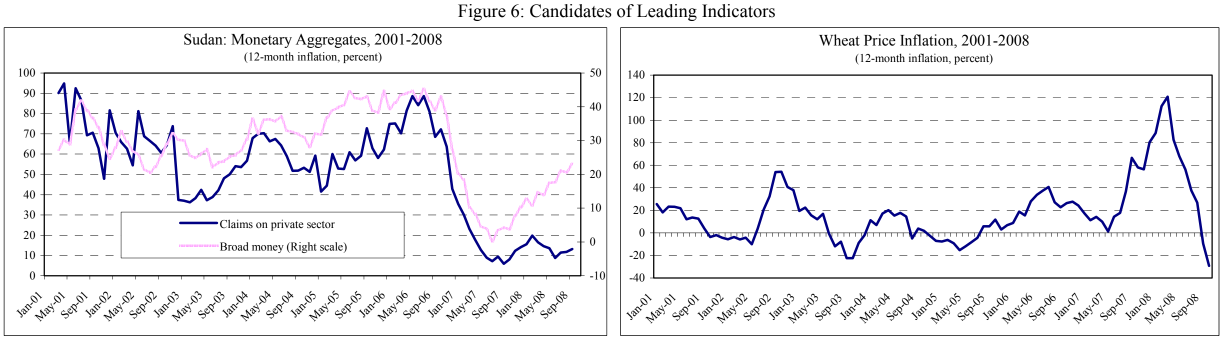
Figure 5: Currency Holdings and Islamic Calendar Dummy Variables, 2005-2008

C. Leading Indicators

Another possible strategy to forecast inflation is to look at the various indicators of inflation. Once the leading indicators of inflation are identified, it is easy for the central bank to forecast inflation by focusing on the developments in them.

Economic theory and the structure of the Sudanese economy suggest that private sector credit, money supply, nominal exchange rate, and world wheat price inflation are good candidates (Figures 6).[12] According to the Phillips curve, growth in private sector credit and money supply should precede inflation, since they are good proxies for aggregate demand and thus the future output gap. Changes in nominal exchange rate (the Sudanese pound vis-à-vis U.S. dollar) should also affect inflation through the path-through effect. Lastly, a change in world wheat price is a good proxy for supply shocks in the Phillips curve, reflecting its huge fluctuations in the past and its share in the CPI in Sudan.

Figure 6: Candidates of Leading Indicators



[12] The effects of money supply, nominal exchange rate, output, and foreign prices on inflation in Sudan have been examined by applying the VAR model in Moriyama (2008).

Granger causality is used to assess whether these variables are useful in forecasting inflation.[13] The basic idea of the test is that if an event *A* is a cause of another event *B*, then the event *A* should precede the event *B*. Accordingly, a variable can be used as the leading indicator to forecast inflation when it is concluded to "Granger cause" inflation by the test. In order to maintain the robustness of the test, the paper conducts the test for private sector credit, money supply, nominal exchange rate, world wheat price inflation, and inflation using different lags—from 9 to 18 months, consistent with the estimated time lag that monetary policy change affects inflation in Sudan: about one and half year.[14]

IV. Results

A. ARMA Model

Table 1 reports the estimates of the best ARMA models from ARMA (*p*, *q*) model for $p = 0,...,6$ and $q = 1,...,6$ using the data of the 3-month average inflation[15] from January 2000 to October 2008[16] for three cases: (i) the baseline ARMA model, (ii) the ARMA model with fuel subsidy reduction dummy variables, and (iii) the ARMA model with Islamic calendar variables. Table 2 reports the main statistics—adjusted R^2, the standard error of regression, the Akaike Information Criterion (AIC), the Schwartz Information Criterion (SIC), the Breusch-Godfrey Lagrange Multiplier test statistics for serial correlation, and the Jarque-Bera test statistics for the normal distribution—for all ARMA (*p*, *q*) model for $p = 0,...,6$ and $q = 1,...,6$ in order to examine how the choice of (*p*, *q*) affects the main statistics.

In all cases, ARMA (4, 5)—four autoregressive terms and five moving average terms—is the best model to forecast inflation (the 3-month average inflation) in Sudan. The ARMA (4, 5) with the fuel subsidy reduction dummy variables has the smallest standard error of regression. The marginal significance of the Islamic calendar variables—in sharp contrast to past studies in which these variables are significant—may be due to averaging inflation over 3 months in order to eliminate very short-term fluctuations which the central bank should ignore for its monetary policy, since shocks related to the Islamic calendar are short term in the framework. For the liquidity forecasting exercise, however, the use of Islamic calendar variables improves the results.

The fitness of the estimated ARMA models to the actual inflation during the sample period (January 2000 to October 2008) is striking (Figure 7). The adjusted R^2, over 0.9 in all cases,

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[13] See Hamilton (1994) for more detailed discussions.

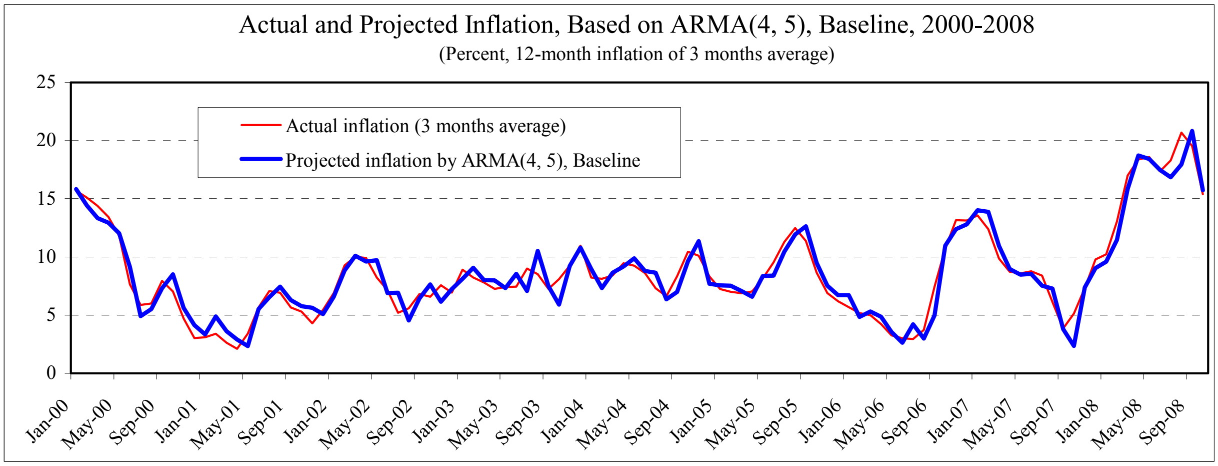
[14] Moriyama (2008).

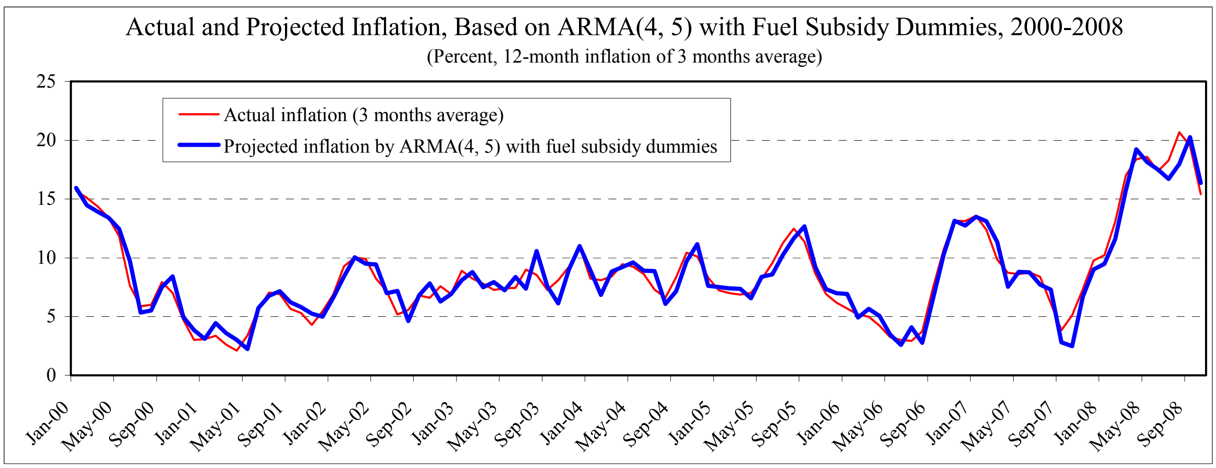
[15] The estimated ARMA models using the original—without applying the 3-month moving average—only poorly track the actual inflation (the adjusted R^2 is most 0.5) and fail to pass the specification tests.

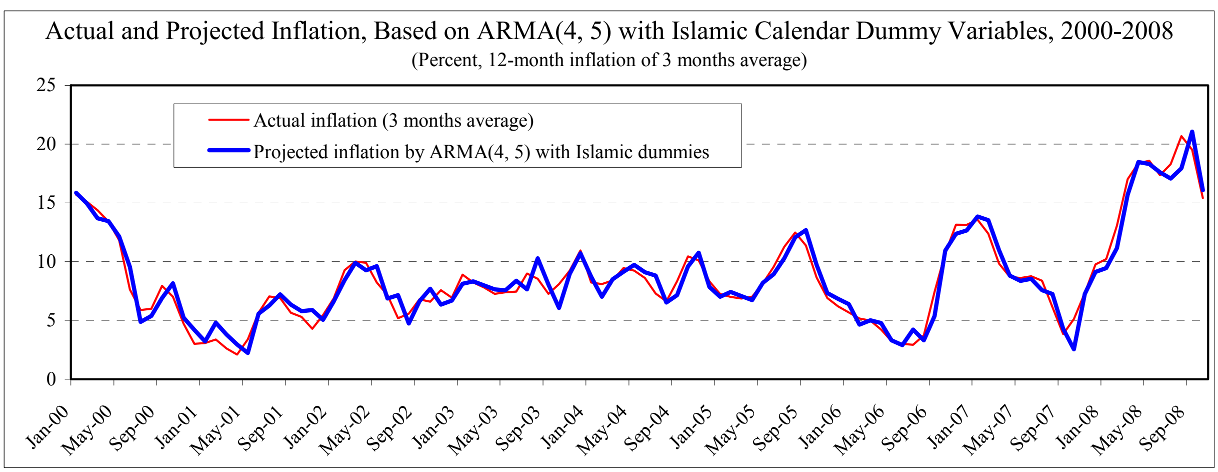
[16] Appendix II reports similar exercise for broad money growth and private credit growth.

suggests that over 90 percent of the fluctuations of inflation can be explained by the estimated ARMA model consisting of only lags of inflation and residuals. Also, the standard error of regression is only around one percentage point, implying that the 95 percent confidence interval of the model during the sample period is at most plus/minus 2 percentage points from the inflation based on the estimated model. This is surprisingly small compared to the average inflation during the sample period.

Figure 7: Actual and Projected Inflation Based on the Estimated ARMA Models







B. Granger Causality Tests for Leading Indicators

The results of the Granger causality test for inflation show that growth in private sector credit and world wheat prices cause inflation in Sudan (Table 3). These two indicators are therefore used for forecasting inflation in this paper. Although the tests detect causality from broad money growth and foreign exchange rate change to inflation with some lags, the p-value of the test statistics is (at most) slightly less than 5 percent, suggesting the causality is not strong. The counter hypothesis—causality from inflation to broad money growth and foreign exchange changes—is (sometimes) marginally significant, implying that broad money and foreign exchange may have the weak two-way causality with inflation instead of the one way causality from broad money and exchange rate to inflation.

The result of the possibility of weak two-way causality between broad money (and the exchange rate) and inflation is not surprising, since the two variables are policy variables for the central bank. If the bank tightens money supply (which leads to exchange rate appreciation in the standard small open economy) in order to contain inflationary pressures, money supply growth (and exchange rate) becomes a function of inflation[17]. This implies another direction of causality in addition to the causality suggested by economic theory: money supply as a proxy of aggregate demand leads to inflation and nominal exchange rate affects inflation through the path-through effect.

V. Implications—What Can Be Said from the Estimated Model and the Tests?

A. Can the Estimated Model Explain the Surge of Inflation in 2007 and 2008?

Although the estimated ARMA (4, 5) model demonstrates remarkable fitness to the actual inflation during the sample period, this does not necessarily mean that the model can forecast inflation in the future. In order to check for the model's forecasting abilities, this subsection simulates the forecasted inflation from July 2007 to end-2008—coincident with the surge of inflation due to world wheat price inflation—using only information available as of end-June 2007 and compares the forecasted inflation with the actual inflation. The discrepancies (or the forecast errors) should be a good indicator of how well the model can forecast the behavior of the out of sample inflation.

This exercise is mathematically equivalent to looking for the projection of inflation and its confidence interval based on the estimated ARMA (4, 5) model with fuel subsidy dummy variables—the specification with the smallest mean squared errors—from July 2007 to December 2008 using information available only as of end-June 2007. While the exercise is analytically possible, computing the projection and its confidence interval is complicated. Therefore, we numerically calculate the projection of inflation and its confidence interval using

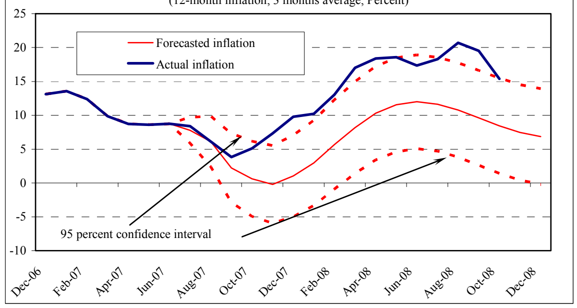
[17] For more discussion on the optimal monetary policy see Gali (2008).

software (MATLAB) that solves the exercise by generating random shocks from the normal distribution and computing the projected path of inflation based on the estimated ARMA model.

The actual simulation is conducted in three steps. First, a time series of random shocks from July 2007 to December 2008 following the estimated distribution of the residuals in the ARMA (4, 5) model is generated and the inflation associated with the random shocks is simulated. Second, the simulation is iterated ten thousands times. Third, the mean and standard deviation of the forecasted inflation is estimated from the observations of the simulated inflation.

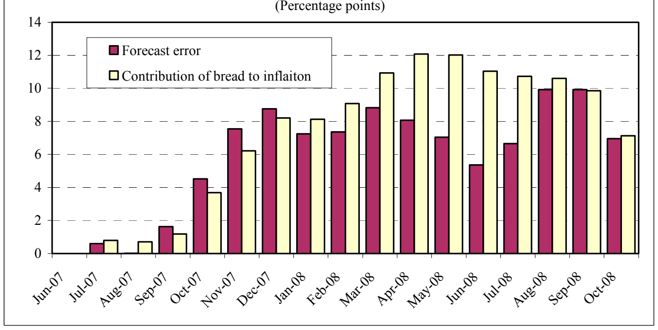
The actual inflation stays outside of the 95 percent confidence interval of the forecasted inflation for most of the simulation period (Figure 8) This suggests that the ARMA (4, 5) with fuel subsidy reduction dummy variables—the best mean squared error model—cannot forecast the surge of inflation in 2007 and 2008. The forecasted inflation (thin line) first declines to nearly zero around November 2007, rises to double digits in July 2008 and gradually decline after that. The actual inflation (thick line) is inside the 95 percent confidence interval until October 2007 but out of the interval after that, except June 2008.

Figure 8:Forecasted Inflation, July 2007-December 2008, as of June 2007
(12-month inflation, 3 months average, Percent)



Almost all of the surge of inflation in 2007 and 2008 was, however, caused by only one item—bread—as a result of the sharp increase in the world wheat prices. Such huge external shock cannot be incorporated in the simulation, since the shocks added to the estimated ARMA (4, 5) model are, by the construction of the model, assumed to follow the normal distribution with zero mean and without serial correlation. Figure 9 clearly shows that most of the forecast errors of the ARMA (4, 5) are attributable to the surge in the contribution of bread price to overall CPI inflation, reflecting the spike in the world wheat prices.

Figure 9: Forecast Errors of the Model and Bread Contribution to Inflation, July 2007-October 2008
(Percentage points)



Once the contribution of bread price to CPI inflation is corrected, the explanatory power of the model improves dramatically, as demonstrated by Figure 10. The actual inflation stays inside the 95 percent confidence interval during the simulation period and the actual inflation tracks the forecasted inflation very well except the second quarter of 2008. Therefore, different from its first appearance, the estimated ARMA model can still explain inflation developments in 2007 and 2008, once the huge external shock is taken into account.

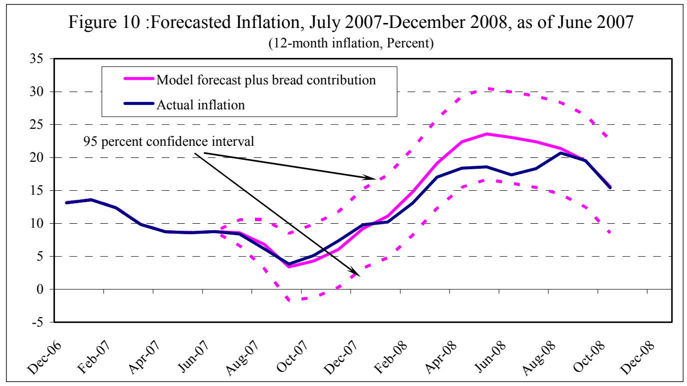


Figure 10 :Forecasted Inflation, July 2007-December 2008, as of June 2007
(12-month inflation, Percent)

B. Forecasting Inflation for 2009 and 2010

A more interesting exercise for the central bank is to forecast future inflation. Following the same procedure and the model ARMA (4, 5) discussed in the previous section, we project inflation based on data available as of October 2008. Given that the model shows very good fitness during the sample period and tracks the actual inflation developments even during 2007 and 2008 once the external shock is incorporated, the forecasted inflation with its confidence interval for 2009 and 2010 should be valuable information in determining monetary policy.

Figure 11 shows forecasted inflation for 2009 and 2010. The figure shows that (i) 3-month average inflation will quickly decline to single digit after November 2008 and will stay in single digits; and (ii) in the absence of an external shock, the surge in inflation in 2007 and 2008 is unlikely to reoccur, as shown by the upper part of the 95 percent confidence interval which is expected to be at most 15 percent during 2009 and 2010.

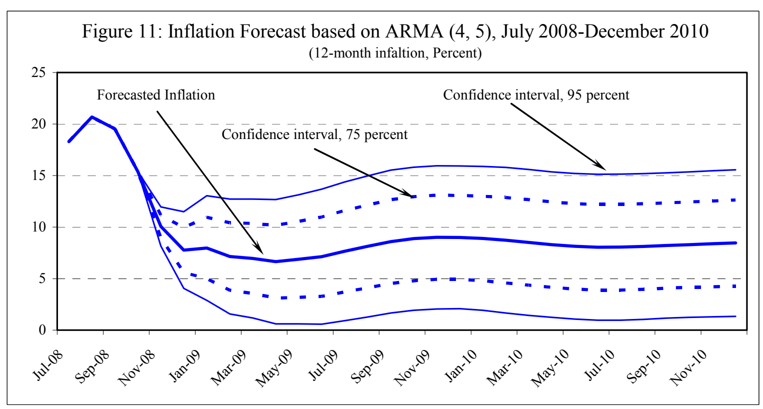


Figure 11: Inflation Forecast based on ARMA (4, 5), July 2008-December 2010
(12-month infaltion, Percent)

C. Leading Indicators (Private Sector Credit Growth and Wheat Price Inflation)

Forecasting inflation based on the leading indicators methodology has an advantage over the estimated ARMA model. While the ARMA model assumes, by its construction, that the error term follows serially uncorrelated normal distribution with zero mean, the central bank can incorporate any expected changes in the forecast of the leading indicators, including external shocks and policy changes. This is in sharp contrast to the forecast method based on the ARMA model.

Private sector credit growth is projected to recover during 2009 and 2010 after its sharp decline due to the accumulation of domestic arrears during the second half of 2006 and 2007, reflecting an assumption of domestic arrears clearance under the baseline scenario.[18] Given other conditions, the recovery should have inflationary pressures through widening the output gap in the future, due to the strong correlation between private sector credit and the final domestic demand. However, less fiscal space associated with lower oil prices may significantly reduce the expected amount of domestic arrears clearance during 2009 and 2010 compared to that originally envisaged under the baseline scenario. Accordingly, recovery of private sector credit growth during 2009 and 2010 may be more gradual, suggesting that inflationary pressures should be smaller.

Figure 12:Oil Price Projections, World Economic Outlook, 2000-2010
(US dollar per barrel)

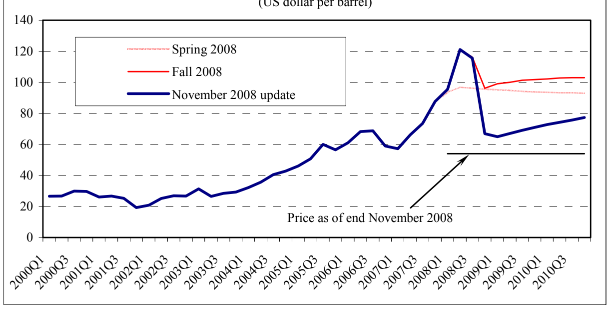
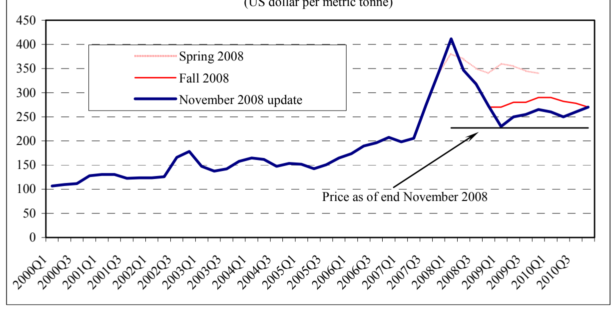


Figure 13: Wheat Price Projections, World Economic Outlook, 2000-2010
(US dollar per metric tonne)



Wheat price would impact inflation through supply side shocks in the Phillips curve, as the surge of world wheat prices significantly increased inflation in 2007 and 2008. World wheat price inflation is declining after hitting its peak in the first quarter of 2008 (Figure 13), suggesting that inflationary pressures associated with world wheat prices will likely be small.

In summary, projections of the two leading indicators selected from the Granger causality test—good proxies for demand side and supply side shocks—suggest that inflationary pressures during 2009 and 2010 will be small, given other conditions, particularly assuming that the authorities will maintain prudent fiscal policies. This result is in line with the simulation in the previous subsection based on the estimated ARMA (4, 5) model: inflation is expected to remain within single digit in 2009 and 2010.

[18] See IMF (2009).

VI. Conclusions

This paper used two methods—the ARMA model and the leading indicators of inflation—to forecast inflation in Sudan. The estimated ARMA model has remarkable explanatory power during the sample period. The estimated model can track the surge in inflation during 2007 and 2008 once the external shock—bread price inflation due to world wheat price inflation—is taken into account. The leading indicators methodology suggests that private sector credit and the world wheat prices play a key role in explaining inflation. Both methodologies suggest that inflation will be in single digit in 2009–10, assuming prudent macroeconomic policies are maintained.

Table 1. Estimated ARMA Model of Inflation
(3-month average and original), 2000-2008 1/

Specification of ARMA	*Baseline ARMA (4, 5)* *3 months average*	*Add Fuel subsidy dummies ARMA (4, 5)* *3 months average*	*Add Islamic Dummies ARMA (4, 5)* *3 months average*
Constant	1.267	1.230	1.363
	(3.865)	(3.464)	(3.488)
AR(1)	1.434	1.450	1.330
	(14.913)	(13.893)	(12.728)
AR(2)	-0.007	-0.165	0.099
	(-0.0422)	(-0.908)	(0.581)
AR(3)	-0.834	-0.727	-0.835
	(-4.395)	(-4.152)	(-4.215)
AR(4)	0.257	0.295	0.243
	(2.206)	(2.764)	(1.824)
AR(5)			
AR(6)			
MA(1)	0.268	0.196	0.300
	(6.508)	(10.560)	(9.569)
MA(2)	-0.571	-0.428	-0.500
	(-10.200)	(-21.367)	(-21.291)
MA(3)	-0.556	-0.418	-0.489
	(-13.883)	(-26.288)	(-24.357)
MA(4)	0.215	0.182	0.273
	(5.353)	(9.640)	(11.515)
MA(5)	0.924	0.940	0.953
	(26.735)	(46.411)	(28.191)
MA(6)			
Fuel1		1.896	
		(2.751)	
Fuel2		-2.642	
		(-3.275)	
Ramadan			0.298
			(1.626)
Dhul-Hijja			-0.201
			(-1.513)
Shawwal			-0.272
			(-1.617)
Adjusted R^2	0.934	0.937	0.937
Standar error	1.012	0.988	0.992
SIC	3.204	3.221	3.263
AIC	2.952	2.920	2.937
LM Test 2/	0.919	0.789	0.125
Jarque-Bera 3/	0.109	0.639	0.406

1/ Number in parenthesis is t-statistics.
2/ Breusch-Godfrey Serial Correlation Lagrange Multiplier Test, p-value to reject the null hypothesis: No serial correlation.
3/ Jaque-Bera Test Statistics for Normality, p-value to reject the null hypothesis: normal distribution.

Table 2. Main Statistics of Various ARMA Models, 2000-08

ARMA specification	Baseline						With Fuel Subsidy Dummies						With Islamic Dummies					
	R^2	*SE 1/*	*AIC*	*SIC*	*LM Test 2/*	*Jarque-Bera 3/*	*R^2*	*SE 1/*	*AIC*	*SIC*	*LM Test 2/*	*Jarque-Bera 3/*	*R^2*	*SE 1/*	*AIC*	*SIC*	*LM Test 2/*	*Jarque-Bera 3/*
(0, 1)	0.691	2.196	4.430	4.480	0.000	0.010	0.688	2.204	4.455	4.556	0.000	0.008	0.684	2.220	4.479	4.605	0.000	0.011
(0, 2)	0.841	1.575	3.774	3.850	0.000	0.000	0.838	1.589	3.810	3.936	0.000	0.000	0.838	1.589	3.819	3.970	0.000	0.000
(0 ,3)	0.909	1.188	3.220	3.320	0.001	0.032	0.900	1.246	3.333	3.484	0.000	0.017	0.910	1.184	3.240	3.416	0.000	0.130
(0, 4)	0.913	1.164	3.187	3.312	0.033	0.039	0.914	1.159	3.196	3.372	0.039	0.013	0.912	1.172	3.228	3.429	0.028	0.072
(0, 5)	0.919	1.122	3.124	3.275	0.266	0.077	0.921	1.109	3.116	3.317	0.010	0.777	0.920	1.118	3.142	3.368	0.028	0.291
(0, 6)	0.920	1.116	3.121	3.297	0.047	0.561	0.920	1.115	3.137	3.363	0.080	0.724	0.920	1.116	3.121	3.297	0.047	0.561
(1, 0)	0.854	1.509	3.680	3.730	0.000	0.607	0.862	1.467	3.642	3.742	0.000	0.621	0.851	1.525	3.728	3.854	0.000	0.742
(1, 1)	0.892	1.299	3.390	3.465	0.003	0.803	0.895	1.276	3.372	3.497	0.007	0.925	0.889	1.313	3.437	3.588	0.004	0.828
(1, 2)	0.917	1.137	3.132	3.233	0.097	0.028	0.918	1.133	3.143	3.294	0.051	0.104	0.915	1.151	3.184	3.360	0.077	0.024
(1 ,3)	0.921	1.112	3.095	3.221	0.152	0.007	0.921	1.107	3.105	3.281	0.144	0.047	0.921	1.109	3.117	3.318	0.057	0.031
(1, 4)	0.922	1.102	3.087	3.238	0.144	0.047	0.923	1.093	3.089	3.290	0.285	0.362	0.922	1.105	3.118	3.344	0.060	0.146
(1, 5)	0.924	1.090	3.074	3.250	0.493	0.142	0.924	1.085	3.082	3.308	0.452	0.515	0.923	1.095	3.108	3.359	0.558	0.264
(1, 6)	0.924	1.088	3.080	3.281	0.371	0.103	0.924	1.087	3.095	3.346	0.611	0.426	0.922	1.105	3.136	3.412	0.301	0.233
(2, 0)	0.899	1.252	3.315	3.390	0.261	0.776	0.903	1.230	3.298	3.424	0.279	0.813	0.897	1.264	3.361	3.512	0.272	0.213
(2, 1)	0.900	1.245	3.314	3.414	0.047	0.789	0.904	1.224	3.298	3.449	0.124	0.869	0.898	1.258	3.361	3.537	0.140	0.892
(2, 2)	0.916	1.143	3.151	3.276	0.109	0.028	0.917	1.139	3.161	3.337	0.036	0.098	0.914	1.157	3.202	3.403	0.085	0.034
(2 ,3)	0.920	1.113	3.107	3.258	0.378	0.008	0.924	1.091	3.084	3.285	0.102	0.094	0.918	1.129	3.162	3.388	0.010	0.571
(2, 4)	0.923	1.096	3.086	3.262	0.285	0.017	0.923	1.099	3.107	3.333	0.245	0.039	0.923	1.095	3.109	3.360	0.005	0.206
(2, 5)	0.929	1.049	3.005	3.206	0.508	0.001	0.935	1.006	2.940	3.192	0.710	0.035	0.933	1.025	2.985	3.262	0.083	0.239
(2, 6)	0.929	1.050	3.016	3.242	0.987	0.001	0.934	1.015	2.967	3.243	0.826	0.014	0.931	1.036	3.014	3.316	0.983	0.251
(3, 0)	0.902	1.239	3.303	3.403	0.016	0.675	0.905	1.217	3.285	3.436	0.049	0.704	0.900	1.250	3.348	3.524	0.009	0.817
(3, 1)	0.901	1.245	3.321	3.447	0.006	0.657	0.904	1.222	3.303	3.479	0.039	0.636	0.899	1.255	3.365	3.566	0.006	0.767
(3, 2)	0.925	1.084	3.054	3.204	0.577	0.032	0.926	1.070	3.047	3.248	0.082	0.246	0.924	1.088	3.088	3.314	0.539	0.100
(3 ,3)	0.922	1.100	3.093	3.269	0.181	0.024	0.925	1.083	3.078	3.304	0.120	0.197	0.916	1.144	3.197	3.448	0.018	0.592
(3, 4)	0.928	1.062	3.030	3.231	0.340	0.000	0.932	1.026	2.979	3.230	0.190	0.000	0.929	1.054	3.041	3.317	0.318	0.029
(3, 5)	0.929	1.053	3.023	3.249	0.630	0.001	0.935	1.008	2.953	3.229	0.638	0.008	0.932	1.028	2.999	3.301	0.539	0.391
(3, 6)	0.925	1.079	3.079	3.330	0.242	0.235	0.933	1.019	2.981	3.283	0.761	0.005	0.924	1.088	3.121	3.447	0.048	0.529
(4, 0)	0.901	1.245	3.322	3.447	0.011	0.655	0.904	1.223	3.304	3.480	0.050	0.658	0.899	1.256	3.366	3.567	0.010	0.787
(4, 1)	0.902	1.236	3.316	3.467	0.010	0.575	0.914	1.160	3.208	3.409	0.044	0.886	0.909	1.193	3.272	3.498	0.063	0.927
(4, 2)	0.922	1.101	3.094	3.269	0.868	0.205	0.925	1.082	3.077	3.303	0.429	0.265	0.920	1.113	3.142	3.393	0.835	0.291
(4 ,3)	0.924	1.087	3.078	3.279	0.278	0.052	0.927	1.065	3.054	3.305	0.182	0.204	0.917	1.138	3.194	3.471	0.026	0.611
(4, 4)	0.928	1.060	3.036	3.262	0.646	0.000	0.927	1.066	3.064	3.340	0.339	0.180	0.932	1.027	2.998	3.299	0.411	0.183
(4, 5)	0.934	1.012	2.952	3.204	0.919	0.109	0.937	0.988	2.920	3.221	0.789	0.639	0.937	0.992	2.937	3.263	0.125	0.406
(4, 6)	0.924	1.086	3.100	3.376	0.159	0.202	0.937	0.991	2.934	3.260	0.853	0.447	0.934	1.012	2.984	3.336	0.937	0.659
(5, 0)	0.910	1.187	3.236	3.387	0.202	0.617	0.913	1.162	3.210	3.411	0.380	0.839	0.908	1.197	3.279	3.505	0.300	0.826
(5, 1)	0.909	1.193	3.255	3.431	0.157	0.616	0.912	1.168	3.229	3.455	0.233	0.839	0.907	1.203	3.297	3.549	0.173	0.821
(5, 2)	0.915	1.148	3.187	3.388	0.550	0.843	0.923	1.099	3.115	3.367	0.737	0.986	0.914	1.155	3.223	3.500	0.548	0.768
(5 ,3)	0.922	1.103	3.115	3.341	0.397	0.014	0.927	1.066	3.063	3.340	0.855	0.193	0.922	1.104	3.142	3.443	0.011	0.710
(5, 4)	0.929	1.055	3.035	3.286	0.138	0.080	0.933	1.019	2.981	3.283	0.418	0.017	0.923	1.099	3.141	3.467	0.697	0.341
(5, 5)	0.928	1.057	3.047	3.324	0.531	0.004	0.938	0.985	2.921	3.248	0.558	0.282	0.937	0.993	2.947	3.298	0.076	0.532
(5, 6)	0.930	1.046	3.034	3.336	0.150	0.788	0.937	0.989	2.939	3.291	0.633	0.268			MA is invertible			
(6, 0)	0.909	1.192	3.253	3.429	0.196	0.574	0.913	1.166	3.226	3.452	0.245	0.793	0.907	1.201	3.294	3.545	0.224	0.768
(6, 1)	0.909	1.189	3.257	3.458	0.220	0.491	0.913	1.163	3.230	3.481	0.557	0.606	0.909	1.188	3.281	3.557	0.377	0.808
(6, 2)	0.912	1.170	3.234	3.460	0.379	0.465	0.922	1.103	3.131	3.408	0.799	0.980	0.908	1.195	3.300	3.601	0.437	0.807
(6 ,3)	0.923	1.093	3.106	3.357	0.616	0.040	0.913	1.163	3.246	3.547	0.233	0.502	0.913	1.164	3.256	3.583	0.022	0.970
(6, 4)	0.929	1.051	3.036	3.313	0.086	0.005	0.922	1.100	3.144	3.470	0.279	0.934	0.911	1.180	3.291	3.643	0.118	0.984
(6, 5)	0.927	1.063	3.066	3.368	0.364	0.004	0.936	0.999	2.958	3.310	0.308	0.708	0.910	1.186	3.309	3.686	0.094	0.991
(6, 6)	0.931	1.039	3.029	3.355	0.125	0.487	0.936	1.001	2.971	3.348	0.037	0.534	0.913	1.163	3.279	3.681	0.000	0.840

1/ Standard error of regressions.
2/ Breusch-Godfrey Serial Correlation Lagrange Multiplier Test, p-value to reject the null hypothesis: No serial correlation.
3/ Jaque-Bera Test Statistics for Normality, p-value to reject the null hypothesis: normal distribution.

Table 3. Granger Causality Tests Between Inflation and Leading Indicators, 2000-2008

# of lags	CPI inflation (3 months average) vs. Private Credit growth		Result of the Test 3/
	From CPI to Private Credit 1/	From Private Credit to CPI 2/	
9	0.064	0.004	Private credit cause inflation.
12	0.119	0.002	Private credit cause inflation.
15	0.431	0.049	Private credit cause inflation.
18	0.124	0.019	Private credit cause inflation.

# of lags	CPI inflation (3 months average) vs. Broad Money		Result of the Test 3/
	From CPI to Money 1/	From Money to CPI 2/	
9	0.034	0.010	Both cause each others.
12	0.138	0.045	Money causes inflation.
15	0.321	0.041	Money causes inflation.
18	0.398	0.086	Cannot conclude causality.

# of lags	CPI inflation (3 months average) vs. World Wheat Price Inflation		Result of the Test 3/
	From CPI to Wheat Price 1/	From Wheat Price to CPI 2/	
9	0.444	0.011	World wheat price causes inflation.
12	0.601	0.095	Cannot conclude causality.
15	0.106	0.028	World wheat price causes inflation.
18	0.396	0.048	World wheat price causes inflation.

# of lags	CPI inflation (3 months average) vs. Foreign Exchange Change		Result of the Test 3/
	From CPI to FX 1/	From FX to CPI 2/	
9	0.117	0.062	Cannot conclude causality.
12	0.092	0.070	Cannot conclude causality.
15	0.218	0.121	Cannot conclude causality.
18	0.207	0.041	FX causes inflation.

1/ Number is p-value for the null hypothesis "Inflation does not cause private credit growth <World wheat price>).
2/ Number is p-value for the null hypothesis "Private credit growth <World wheat price> does not cause inflation).
3/Test is based on 5 percent significant level.

APPENDIX I: The Schwartz Information Criterion[19]

The Schwartz Information Criterion (SIC) statistics summarizes the fitness of the model counting the loss of degree of freedom by adding parameters. According to the criterion, the best model should minimize the following:

$$SIC = \log(SSR_j / n) + (j+1)\frac{\log(n)}{n} \quad \text{(A1)}$$

where SSR_j is the sum of squared residuals for the autoregression with j lags, and n sample period.

Equation (A1) suggests that the SIC requires the best model to balance the trade-off between the sum of squared residuals and the number of parameters included in the model. While adding new explanatory variables will reduce the sum of squared residuals, the model needs to pay a cost of increasing parameters, which is captured by the second term in equation (A1). The latter point will be much clearer to compare the SIC with the Akaike Information Criterion (AIC), another statistics commonly used for selecting the length of lags, which has $2/n$ instead of $\log(n)/n$ in the second term on the right hand side of equation (A1). The SIC is a more appropriate indicator to measure the fitness of the model than the AIC when the sample period is longer than 7.

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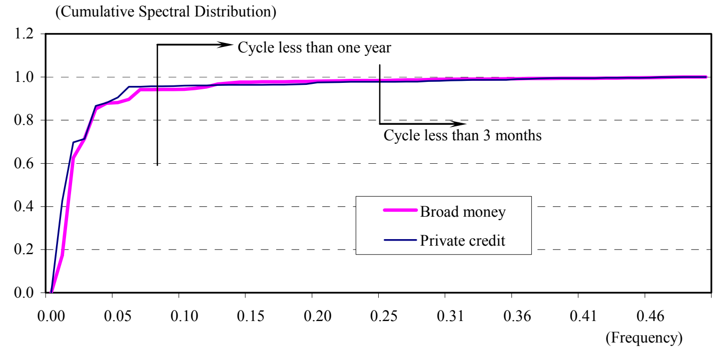
[19] This Appendix is based on Hayashi (2000).

Appendix II: Estimated ARMA Model for Main Monetary Aggregates

This appendix conducts the same exercise as in sections II and III for main monetary aggregates: broad money growth and private sector credit growth.

Results of the spectral analysis suggest that 12-month growth of broad money and private sector credit has only a small share of fluctuations with cycles shorter than 3 months, suggesting no need to average the original 12-month growth rate in order to eliminate very short-term noises. Even the share of fluctuations whose cycles are shorter than one year is less than 5 percent.

Figure A1: Cumulative Spectral Distribution of Monetary Aggregates, 2000-2008 (Frequency domain, based on monthly data, 12-month growth)



Like the estimates of the ARMA model for inflation, the best ARMA model to forecast broad money growth and private sector credit growth needs to satisfy three conditions: (i) error terms should not be serially correlated with each other; (ii) error terms should follow the normal distribution; and (iii) the best model should have the smallest SIC value. Table A1 reports the two best ARMA models to forecast broad money growth and private sector credit growth, respectively. The fitness of the estimated ARMA model is very well, as demonstrated by Figure A1.

Figure A2: Actual and Projected Monetary Aggregates by the Estimated ARMA Models

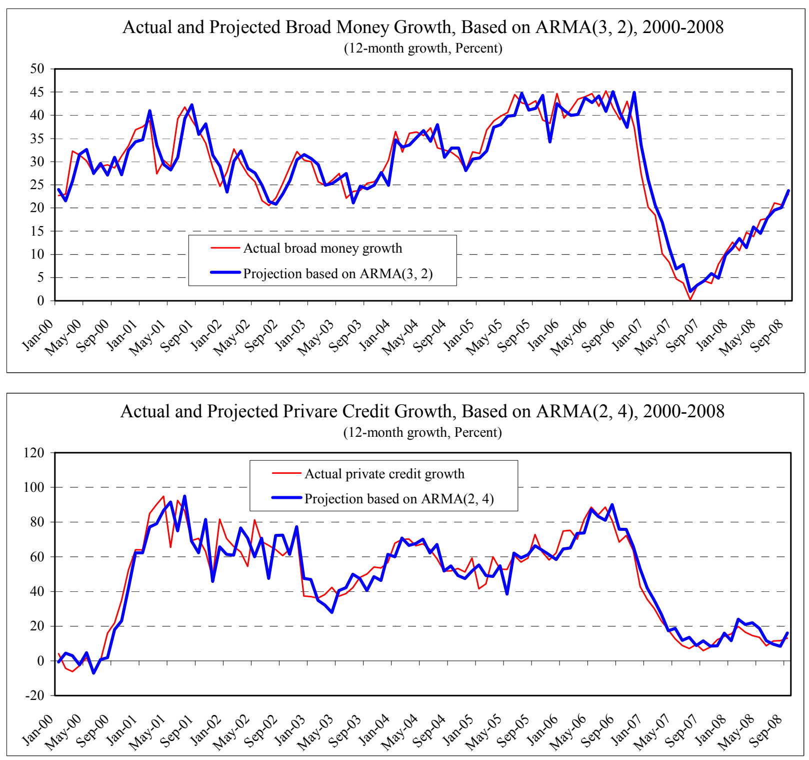


Table A1. Estimated ARMA Model of Broad Money, 2000-2008 1/

Specification of ARMA	Broad money growth		Private Sector Credits	
	ARMA (3, 2)	*ARMA (2, 4)*	*ARMA (2, 5)*	*ARMA (3, 4)*
Constant	4.782	7.203	8.402	7.768
	(1.640)	(2.278)	(2.271)	(2.035)
AR(1)	-0.574	0.033	0.185	0.149
	(-6.805)	(0.459)	(1.812)	(1.159)
AR(2)	0.794	0.701	0.628	0.619
	(14.290)	(9.512)	(6.327)	(6.314)
AR(3)	0.608			0.059
	(7.079)			(0.494)
AR(4)				
AR(5)				
AR(6)				
MA(1)	1.816	1.245	0.631	0.643
	(28.406)	(11.795)	(16.091)	(15.134)
MA(2)	0.995	0.561	-0.131	-0.120
	(14.887)	(3.190)	(-2.051)	(-1.829)
MA(3)		0.461	0.502	0.491
		(2.582)	(8.053)	(7.159)
MA(4)		0.550	0.892	0.882
		(5.007)	(19.750)	(18.269)
MA(5)				
MA(6)				
Adjusted R^2	0.918	0.917	0.901	0.900
Standar error	3.123	3.131	8.481	8.515
SIC	5.425	5.464	7.457	7.498
AIC	5.197	5.211	7.204	7.220
LM Test 2/	0.307	0.109	0.430	0.585
Jarque-Bera 3/	0.840	0.751	0.498	0.516

1/ Number in parenthesis is t-statistics.
2/ Breusch-Godfrey Serial Correlation Lagrange Multiplier Test, p-value to reject the null hypothesis: No serial correlation.
3/ Jaque-Bera Test Statistics for Normality, p-value to reject the null hypothesis: normal distribution.

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